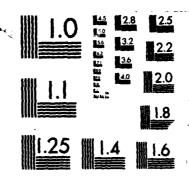
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Long Term Statistical Measurements of Environmental Acoustics Parameters in the Arctic

AEAS Report No. 2 - Low Frequency Transmission Loss Measurements in the Central Arctic Ocean

B. M. Buck

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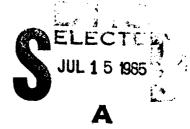
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This is one of a series of tech acoustics data collected between Laboratory, Inc. for various nation taken using manned ice camps and measured using arctic data budy NOAA series satellites. The	en 1970 and the pray agencies. Property agencies. Property and and any stated to that operated to the second second to the second secon	resent by Polar Research bagation loss data were nbient noise levels were through the NIMBUS 6 and

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Report No. 2) addresses propagation loss in deep water (i.e., over 1000 m) of the Central Arctic Ocean at low frequencies (10-500 Hz). The data were taken primarily from underwater shots, although some CW data are included, at source depths between 18.3 m and 243.8 m. Receiving hydrophones were at depths between 9 and 91 m. Other data in the tabulations include for the source: station name, type, depth below sea level and below the ice, nominal TNT yield, measured yield, latitude and longitude, water depth, and source energy at the analysis frequencies. For the receiver: station name, hydrophone depth below sea level and below the ice, latitude and longitude, water depth, and received signal energy at the analysis frequencies. For the path: range, bottomside ice roughness, % of path less than 1000 m deep, % of path over an abyssal plain, mean path depth, and minimum depth in the path. Key words: These data are contained in the appendices, with each corresponding to a different source depth.

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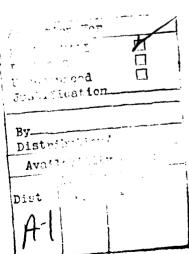
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- Figure 2. Typical SVP's to the west and east of the front in the Greenland-Svalbard strait
- Figure 3. Approximate positions of manned propagation ice stations (1970-1984)
- Figure 4. Best estimate of underside ice roughness in standard deviation about the mean ice depth

Appendices

1.	TL	data	for	source	depth	18.3	m	(60 ft	:)
2.	**	11	11	11	11	61	m	(200 1	ft)
3.	11	11	11	11	11	91.4	m	(300 1	ft)
4.	11	11	11	11	n	121.9	m	(400 1	ft)
- •	**				"	182.9	m	(600 f	ft)
6.	11	11	11	11	11	243.8	m	(800 1	ft)





ARCTIC Environmental Acoustics Data report No. 2

General Background

This is intended as one of a series of "Data Reports" on Arctic environmental acoustics drawn from a base collected by Polar Research Laboratory, Inc. over the years 1970 to the present under contracts with the Office of Naval Research (Undersea, Acoustics, Technology and Arctic Branches), the Arctic Submarine Laboratory NOSC and the Naval Electronics Systems Command, Code 612. Sponsorship of this analysis and reporting effort is from the ASW Environmental Acoustics Support office of the Naval Oceanographic Research and Development Activity through contract NO0014-84-C-0394 with the Office of Naval Research, Arctic Branch. The data, to be presented in several volumns and distributed as completed, will cover propagation loss measurements primarily from underwater shots but also including some CW experiments from manned ice camps, and ambient noise measurements made from Arctic data buoys using the NIMBUS 6 and NOAA series satellites. The data are to be presented in a form of "first-level" statistical analysis. That is, in its primary form suitable for distribution to those interested in Arctic acoustics, in much the oceanographic data is distributed after a typical cruise. It is intended that higher level analyses can be made from these reports and other available data by those wishing to do so. Some of the data have already received such treatment and were reported in various journals and technical reports (see, for example, references 1 through 7).

Data Collection Instrumentation

For the collection of both propagation loss and ambient noise data, single omni hydrophones at various depths under the ice were used. These units were acceleration-cancelling phones mounted from cable

suspensiions designed to minimize "flutter" and "bounce" self-noise. In some cases these suspensions were link chain to a 11 kg (25 pound) weight, and others used a Kevlar "hair faired" electromechanical cable, also to a 11 kg weight. All phones were made neutrally buoyant and decoupled from the suspension to further decrease flutter effects. They were covered with "hairs" of polypropalene to minimize flow-generated noise and to attain neutral buoyancy. All were calibrated at either TRANSDEC/NOSC, Underwater Sound Reference Detachment/ONR, or at PRL using secondary standards from the former labs. Considerable pains were taken in the field to assure that the systems were not contaminated from nearby ice camps or icebreakers. This was accomplished by operating from small, remote, "quieted" ice camps, where all equipment was designed to be battery-operated. The data buoys, of course, were completely uncontaminated by the presence of manned activities.

Several experiments were conducted to measure the effectiveness of the hydrophone suspension system in eliminating, or at least minimizing, self noise caused by the shear current (primarily from wind-driven ice movement). One technique used for this was reported in reference 8. It was concluded from these experiments that the measurements at 10 Hz and above were affected very little by self noise. However, measurements below 10 Hz were affected somewhat, and therefore should be viewed with caution. An analysis is underway at this time to determine the degree of this contamination below 10 Hz. This is being done by performing statistical correlations between measured ice speed (the prime producer of shear current, especially in the Central Arctic) self-navigating ambient noise data buoys and 3.2 and 5 Hz noise level measurements, and between the latter and tabulated seismic activity in the Arctic area. Various experiments have indicated the possibility that seismic activity leaking into the Arctic Basin via T-phase can affect the noise spectrum below 10 Hz.

Explosives used in the propagation work at short ranges were: standard Signal, Underwater Sound (SUS) 0.8 kg (1.8 pound) charges Mk 61 (18 and 244 meters - 60 and 800 feet); Mk 82 (18 and 91 meters - 60 and 300

feet); and specially modified Mk 61s for detonation at 61 m (200 ft), 122 m (400 ft) and 183 m (600 ft) - dropped through ice holes at manned ice camps and from low-flying aircraft into open leads. For the longer ranges, these charges were augmented with block charges of TNT, where the SUS were used to detonate the larger charges. Ranges were measured by various means of navigation including fixes from Transit satellite receptions and bubble sextant sun lines from the ice and Omega receivers aboard the aircraft. In many cases the bubble pulse interval of the explosive was monitored using low-sensitivity phones in the vicinity of the charges, in order to determine effective TNT yield for source energy calculations. However, in other cases this was not feasible.

The ambient noise data buoys were first employed in the Beaufort Sea in the spring of 1975 and used the NIMBUS 6 satellite, with its Random Access Measurement System (RAMS) for navigation and retrieving noise level, atmospheric pressure and air temperature data. The data handling limitations of that satellite system constrained the measurements to four 1/3rd octave bands (3.2, 10, 32 and 1000 Hz for some buoys and 10, 32, 100 and 1000 Hz for others). The levels at those frequencies were sampled at each of the eight, 3-hourly synoptic weather times (0000, 0300, 0600....Z) each day. Those data buoys, called "SYNRAMS" for Synoptic RAMS, were used primarily in the western Central Arctic and are described in reference 9. When the TIROS ARGOS (NOAA series) satellite became available, the activity had shifted to the Eurasian Basin of the Central Arctic and were used there. ARGOS enabled more precise navigation (200-300 m circular probable error) and more data throughput. The SYNARGOS data buoy, described in detail in reference 10, saw its first use in 1980 and makes measurements of ambient noise level in eleven 1/3rd octave bands spaced between 5 and 1000 Hz in some cases, and 5 to 300 Hz in others. All bands are sampled at the weather synoptic times every three hours, the same as SYNRAMS buoys. filter output is averaged with a constant bandwidth averaging time product of 32 Hz seconds. The data are rough-processed by Service ARGOS and sent to PRL in the form of digital tape recordings every two weeks.

At PRL the hydrophone calibrations, preamp gain, bandwidth corrections and other system gains are applied to derive the spectrum levels of ambient noise at each 1/3rd octave filter center frequency.

The buoys are batteried to live for a full year, however, because of the continuous movement of the ice out of the basin and the deployment locations used, the average lifetime attained in the Eastern Central Arctic is on the order of ten months. Each buoy collects a large amount of sampled data - for example, 2,640 independent measurements each month, or about 26,400 measurements during a typical 10 month lifespan. Some of the SYNRAMS data buoys in the Beaufort Sea were active for over a year, one attaining a two year productive life. Although no array is involved, and the measurements are straightforward omni. 1/3rd octave levels. the enable buoys measurements uncontaminated by artifacts in areas and in seasons that impractical of collection by any other means at the present time. provide large data bases that allow true statistical portrayal of the background noise, and get around the constraints of spring-only manned ice camps in the Central Arctic. At present there are ongoing developments to extend the Arctic data buoy to study directional qualities of the noise background, signal and noise propagation loss (using an expendable projector) and the effects of hydrophone depth on both signal and noise. While they will add significantly to the knowledge of the acoustic noise background. will not supplant or detract from the value of the 1/3rd octave omni buoys that are the subject of this series of reports.

With one exception, all of the SYNRAMS and SYNARGOS data buoys employed a hydrophone at 30.5 m (100 feet) below sea level, or about 27.4 m (90 feet) below the bottomside of the ice. One SYNARGOS buoy had phones at four depths: 9 m (30 ft), 30.5 m (100 ft), 61 m (200 ft), and 91 m (300 ft) below sea level. In the data to be presented, the various buoys are identified by their "ARGOS identification number" (I.D.).

Reporting Areas

For ambient noise the measurements will be given in separate reports by geographic areas of the Arctic and its adjacent seas. Figure 1 gives the areas for this and the future ambient noise reports. Figure 1 does not mean to imply that the data buoys evenly covered each of the areas - only that the buoys were in a specified area. These areas are: (1) the North Barents Sea; (2) the West Greenland Sea; (3) the East Central Arctic Ocean (i.e., the Eurasian Basin demarked by the Lomonosov Ridge on one side and the 1000 m curve on the other); (4) the West Central Arctic; (5) the Kara Sea; and (6) the Chukchi Sea. This preliminary area selection was somewhat, but not entirely, arbitary. For example, areas (3) and (4) are probably not statistical different, but the measurements were separated by several years and used different type buoys. Area (1) and most of (2) are shallow, and close to the ice edge, but area (2) is one of very rapid ice movement. Areas (5) and (6) are shallow and widely separated from the other "second-level" analyses are done on the presently reported data and new data sets collected, it will probably result in a different arrangement of areas. For the present, however, the areas of Figure 1 will suffice as a means of separating the data into reasonable-sized reports.

The Present Report

General

The propagation data that are the subject of this report were collected by PRL personnel over the period 1970 to the present, primarily in Areas 3 and 4 of Figure 1 (i.e., Central Arctic), but also in the deep water portion of the northernmost part of Area 2. Most of the data are from underwater shots, although some are from low frequency CW projectors installed through the ice at manned ice camps. The sections to follow explain the various entries in the data set that is contained in the appendices.

Explanation of Entries in the Appendices

Ocean Category (C-Central; F-Front)

Most of the data entries are for the Central Arctic, where the vertical temperature and salinity distribution, and thus the sound speed profile, changes little either in time or over significant horizontal distances. Exceptions to these homogeneous sound speed conditions may occur in the near surface layer due to melting/freezing processes (however, these exceptions will have minimal effect at the very low frequencies that are the subject of this report). The sound velocity profile (SVP) there is characterized by a multi-gradient structure, with a low gradient in the upper part of the Polar Water (PW) layer and a higher gradient between PW layer and the temperature maximum within the Atlantic Intermediate Water (AIW) layer. There is a low gradient from the AIW temperature maximum to the bottom. See Figure 2 for the typical SVP in that area. The data entries in this zone are marked "C" for "Central Arctic".

Some data were taken in regions of the arctic where horizontal gradients in the sound speed distribution may be significant and noticeably impact low frequency acoustic propagation, notably those taken from Ice Stations Ruby and Pearl in 1977, which were in the

vicinity of the polar front that persists along the edge of the shelf of eastern Greenland and extends north into the Greenland-Svalbard Strait. Shots whose propagation paths crossed part of such a frontal zone are marked "F." To the west of this front, the water is similiar to that of the Central Arctic. To the east, the SVP is different, as exemplified in Figure 2. The SVP in the frontal zone is a combination of the two SVP shown in Figure 2. The assumption that the SVP considered typical of the Central Arctic is indeed that, and matter of some speculation. Measurements made to-date are sparce, leaving many large areas uncovered. Other fronts, where horizontal gradients in the sound speed distrubution are significant, exist in the Marginal Ice Zones of the arctic and, at least, during the summer and fall along the marginal seas. The existance of other polar fronts similiar to that in the Greenland-Svalbard Strait (e.g., between other islands such as Svalbard and Franz Joseph Land) that may extend significant distances into the Central Arctic are unmeasured and unknown at this time.

Date/year

Self-explanatory.

Source Station Name

Figure 3 is a chart of the Arctic Ocean showing the approximate locations of the various ice stations used as either or both shot-deployment or signal receiving stations. It can be used, along with the entries of this column, to locate the general site of the transmission loss (TL) measurements. For more accurate location, see the columns labeled "Source latitude" and "Source longitude."

Source type

Shots of various size have been used to gather the data. These include the Mk 61 SUS (60 or 800 feet nominal detonation depth, and 1.8 lbs TNT loading), the Mk 82 SUS (60 or 300 feet detonation depth and 1.8 lbs TNT), special SUS made from Mk 61s, where the detonation depths were 60 feet and 200, 400, or 600 feet. All of the above were

also used to detonate 55 lb block charges (some designated as "Mk 14s") for some of the measurements, especially those at long range.

Source TNT yield (nominal/measured) (lbs of TNT)

"Nominal" in this case is the TNT loading weight. "Measured" indicates that the bubble pulse frequency was measured at the deployment site. The detonation depth was assumed to be the design depth for the SUS used for detonation. Then, the Weston equation:

$$5/6$$
 1/3 F = (d + 33) / kW

was used to calculate "measured" yield. This value, when available, was used in the source energy calculations (see column "Signal in 1 Hz band").

Source depth (feet)

The designed detonation depth of the SUS used for the initiation of the detonation relative to sea level and the bottom side of the ice above. It is to be noted that shots originating from Ice Island T-3 were deployed under sea ice ("Colby Bay") adjacent to the ice island. T-3 at that time was 100 feet thick and composed of glacial ice. The adjacent sea ice was about 12 feet thick. Unfortunately, the exact orientation of the ice island relative to the propagation paths to floe stations ARLIS 5 and 6 is unknown, but the island is believed to have been in the path. Therefore, some of the rays in the narrow vertical arcs important to long-range propagation would have struck the edge of the island, and others would have impinged on the bottom of the four by seven nautical mile ice island. Therefore, the presence of the island could have affected the T-3 data. In the appendices, the shot depths are listed for the depth below the sea ice, not the ice island ice, since this is strictly true.

Source latitude (degrees)

This is in degrees and decimal degrees - not minutes. North latitude is assumed for all entries.

Source longitude (degrees)

This is in degrees and decimal degrees - not minutes.

Water depth at source (meters)

Water depths were taken from reference 11.

Receiver station name

See Figure 3 for approximate Rocations of the receiving sites.

Receiver depth (feet)

The depth of the receiving hydrophone below sea level and below the bottom of the ice above. PRL deep-water measurements have been confined to the following depths below sea level: 30, 100, 200 and 300 feet. However, a small amount of CW data taken by others at deeper depths have been included.

Rcvr latitude (degrees)

This is in degrees and decimal degrees - not minutes.

Rcvr longitude (degrees)

This is in degrees and decimal degrees - not minutes.

Water depth at receiver (meters)

Water depths were taken from reference 11.

Range (n.mi.)

Selp-explanatory

Roughness (sigma ice bottom) (meters)

This column depicts the current best-estimate of the bottomside ice roughness in the transmission path. The only large-area data extant on this parameter are shown in Figure 4. Part of this figure was from data derived by LeSchack (reference 12) using upward-fathometer paper traces provided by the Arctic Submarine Laboratory (ASL) for three submarine

cruises in the early 60s. One of these cruises was in the summer and the others in winter ice. LeSchack found from the track crossing areas that there was no significant seasonal difference, summer to winter. Also, he found the roughness to be the same for the two winter-ice cruises. During SUBICEX 1-77, FLYINGFISH covered a section of the Eurasian Basin in and north of the Greenland-Svalbard Strait, steaming over 2000 n.mi. to criss-cross the area, using a digital recording system developed by PRL and operated by ASL. T. Lwellen of that lab computer-reduced the recordings in one kilometer segments along the track for mean ice depth, RMS ice roughness, standard deviation ice roughness, max keel and other statistical parameters in the segments. Later these data were contoured for the area (reference 13). The results of reference 12 and 13 are given in Figure 4 where a melding of the two is shown with dashed lines. Limited though it is, Figure 4 is the best information now available on synoptic bottomside ice roughness in the Arctic Ocean. Determinations of its accuracy and year-to-year stationarity must await further collection and analysis of submarine up-fathometer data.

$\ensuremath{\mathtt{Z}}$ of path with depth less than 1000 m

Most of the data of this report is for "deep" arctic water. That is, in most cases the water depth in the path is 1000 m or greater. However, for some shots there were parts of the path that were less than 1000 m. This column indicates the percentage of the path where this is true. Bathymetry data for this were taken from reference 11.

% of path over abyssal plane

The percentage of the propagation path that is over a flat bottom. This is only a rough approximation taken from reference 11.

Mean path depth (meters) Self-explanatory. Minimum path depth (meters)

The minimum water depth anywhere along the propagation path, including that under the source and the receiver.

Received signal frequency (Hz)

This is the center of the analysis band for shots (1/3rd octave analysis band used) and CW (various analysis bands used, but all one Hz or less wide).

Signal in 1 Hz band (dB re 1 erg/cm squared per Hz for shots, dB re 1 uPa squared per Hz for CW)

Shot energy was analyzed in most cases by using analog 1/3rd octave filtering, squaring, integrating and dividing by the acoustic impedance. However, in some cases the signal was digitized and similarly analyzed on a one-Hz basis, averaging the neighbor filters.

Signal is average of --- shots

In some cases several shots of the same yield and depth were used in rapid succession, and all recorded at the receiving station and analyzed individually. In some of those cases only the average of the shot signals were retained. Where that was the case, the number of shots used in averaging is given in this column. In most cases, however, the record for each shot signal has been retained, and the data for those shots are given individually.

Source level (1 yard) (dBre 1 erg/cm squared per Hz for shots and 1 uPa squared per Hz for CW)

In 1970 at the ARLIS 5, ARLIS 6 and Ice Island T3 camps, PRL made a major effort to measure directly the source energies of underwater explosives using CW-calibrated paths. After we compared our results with various theoretical models, we concluded that the "PI Model" of NUSC came the closest to our observed results. Therefore, we used that model to predict source energies of shots of different yield and depth.

Those values, reduced to spectrum level, are found in this column. For the CW entries, various methods of measuring source level were used. For submarine mounted HX-29s we used **SCARF** calibrations and measurements made at close range at the ice stations and monitor hydrophones on the sub. For the Camp 1 and Tristan HLF-3 measurements in 1980 and 1982, we used calibrations provided by NUSC from their Lake Seneca calibrations, and on-site measurements of diaphragm displacement. Other CW projections made by PRL (e.g., using NRAP) were measured by monitoring the diaphragm displacement and also a spaced monitor hydrophone.

TL (1 yd) (dB)

The result of subtracting received signal from source energy (for shots) or source level (CW). Rounding to the nearest 0.5 dB was made. However, the average error is estimated to be more on the order of plus-or-minus 2 dB.

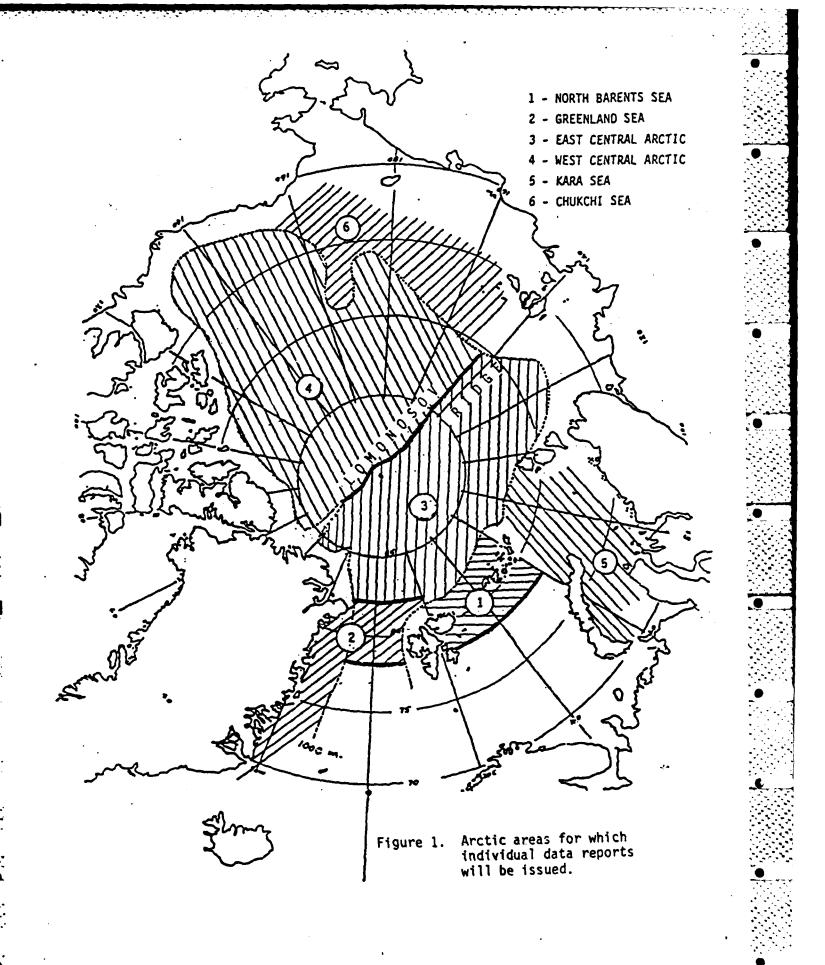
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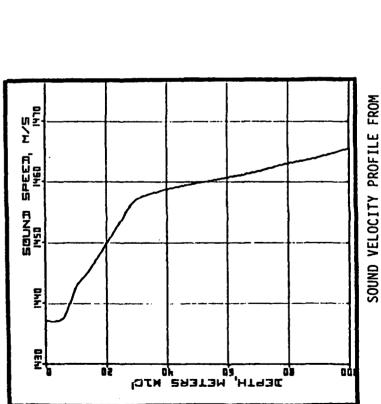
The data are presented in the Appendices by source depths below sealevel.

REFERENCES

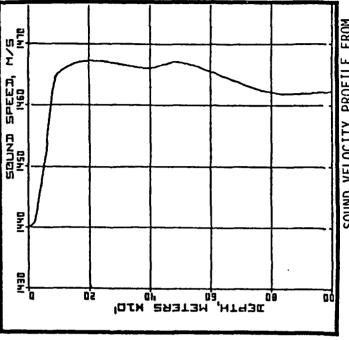
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- (12) "Arctic Ocean ice deformation chart using sonar data recorded from nuclear submarines," L.A. LeSchack, Proc. 7th Int'nl Conf. on Port & Ocean Eng. Under Arctic Conditions (POAC 83), Helsinki, Finland 5-9 Apr. 83.
- (13) "Ice depth and roughness measurements in the Greenland-Svalbard Strait." B.M. Buck (report in preparation)





ARLIS II, WEST OF THE FRONT



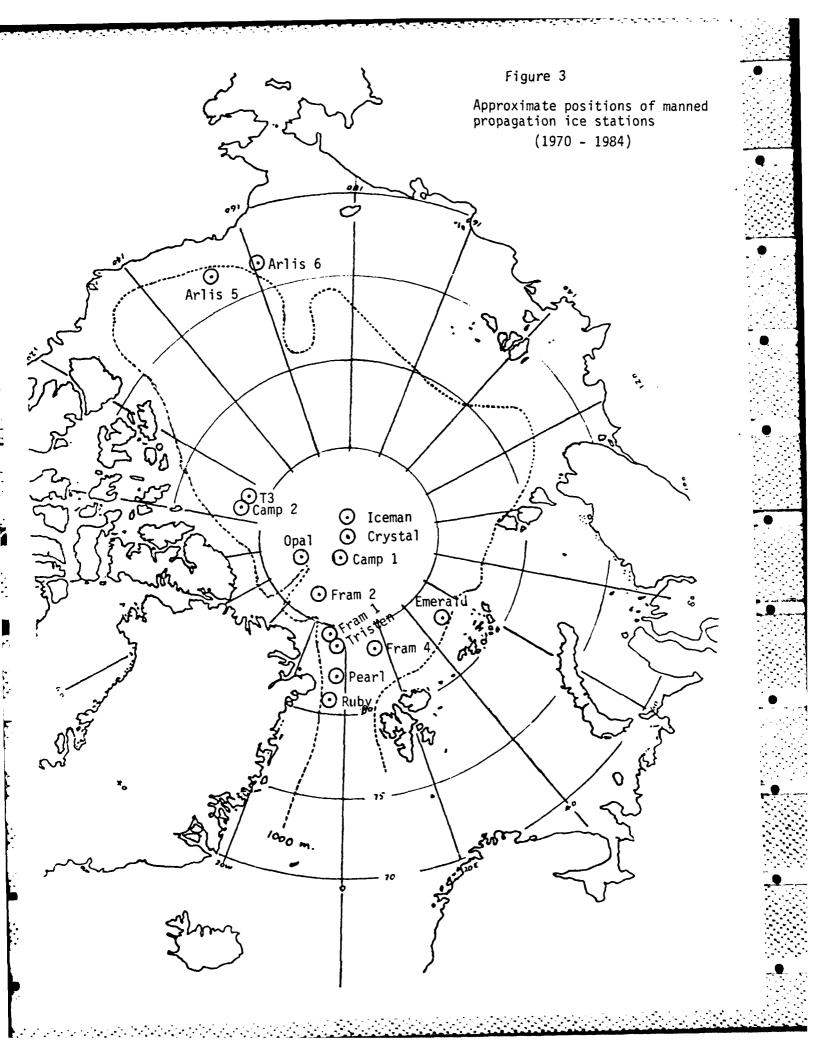
SOUND VELOCITY PROFILE FROM USS ATKA, EAST OF THE FRONT

Figure 2. Typical SVP's to the west and east of the front in the Greenland - Svalbard Strait.

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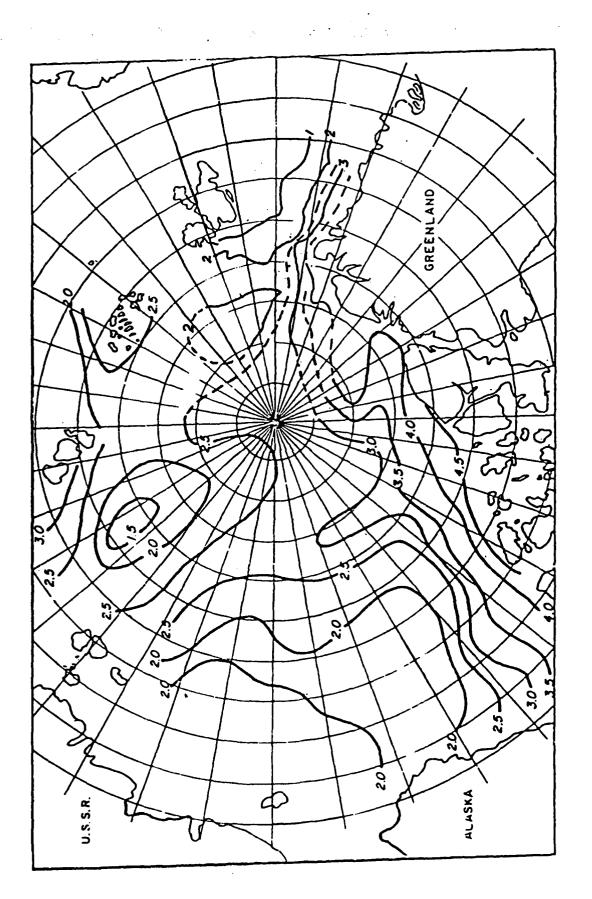


Figure 4. Best estimate of underside ice roughness in standard deviation about the mean ice depth. Contours in meters.

APPENDIX NO. 1

TL Data for Source Depth 18.3 m (60 ft) Below Sea Level

(Note: In the following tabulations, where an entry is absent, the value has not changed from the previous entry in the column.)

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APPENDIX NO. 2

TL Data for Source Depth 61 m (200 ft) Below Sea Level

(Note: In the following tabulations, where an entry is absent, the value has not changed from the previous entry in the column.)

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APPENDIX NO. 3

TL Data for Source Depth 91.4 m (300 ft) Below Sea Level

(Note: In the following tabulations, where an entry is absent, the value has not changed from the previous entry in the column.)

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RCVR LATTER BOTTOM RE SURF/RE ICE BOTTOM	87.24	}_	87.2	87.24		
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APPENDIX NO. 4

TL Data for Source Depth 121.9 m (400 ft) Below Sea Level

(Note: In the following tabulations, where an entry is absent, the value has not changed from the previous entry in the column.)

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APPENDIX NO. 5

TL Data for Source Depth 182.9 m (600 ft) Below Sea Level

(Note: In the following tabulations, where an entry is absent, the value has not changed from the previous entry in the column.)

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APPENDIX NO. 6

TL Data for Source Depth 243.8 m (800 ft) Below Sea Level

(Note: In the following tabulations, where an entry is absent, the value has not changed from the previous entry in the column.)

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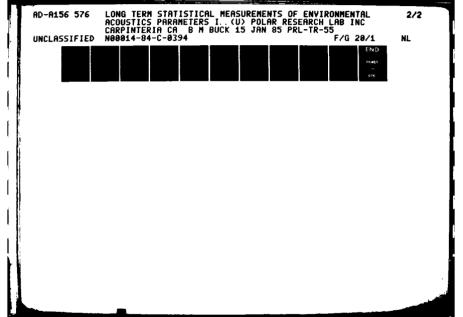
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